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Physical Training Coupled with Non-Invasive Brain Stimulation Modulates Cortical Waves Decreasing the Likelihood of Falls in Adults Elderly with Fragility

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Abstract— Background: *Falls have been implicated as the second highest cause of disability and death in the old population across the world. Some studies have shown that physical exercise applied alone and/or combined with non-invasive brain stimulation (NIBS) may improve mental activity and motor functions reducing the frail and the likelihood of falls. In this research was investigated whether physical and mental exercises training (PMET) combined with the NIBS procedure would reduce better the likelihood of falls in adult's elderly as compared to the PMET by itself.*

Methods: *A rigorous previous selective procedure was used for selecting 57 frail elderly subjects who were later randomly separated into two groups one of which nominated as experimental (FEG) and the other the control group (FCG). The FEG group practiced physical and mental exercises adjointly to a method of non-invasive brain stimulation. The FCG group received the same physical and mental exercises program as the FEG group practiced, but did not pass by the non-invasive brain stimulation procedure. Electroencephalographic data, propensity for falls and reaction time were evaluated in a version of pre and post intervention comparisons. The obtained data were treated using ANOVA ONE WAY with Tukey's posterior test, Kruskal-Wallis followed by Dunn's and Spearman's correlation, all with a significance of 5%.*

Results: *The conjugation of the NIBS to physical and mental training promoted decrease of the propensity for falls, enhance the reaction time, and modulated, both, Alpha and SMR bands. If taken together, it can be assumed that this program, moreover, was also efficient to reduce the adult's elderly of the experimental group their physical and mental frailty as indicated by their frailty test scores taken comparatively between the pre to the post intervention performances.*

Conclusion: *It was concluded that the intervention program here proposed decreased the probability of falls in the adults elderly and being this benefit clearly correlated with cortical modulation of the Alpha and SMR waves and was also efficient to promote the enhancement of those individual's capability to executive functions performance.*

Keywords— Brain stimulation, Physical Exercises, Mental Exercises, EEG, Frailty, Falls, Aging.

I. INTRODUCTION

Falls which many times occur with elderly adults have been implicated as the second highest cause of disability and death in this age group [1]. In part, these events derive from the aging process which is accompanied by structural and functional organic changes that restrict the effectiveness of most of daily actions which many elderlies are subject on their common life, including an ample class of motor activities [2].

In Brazil, as in many other countries, the aging rate is increasing quickly, leading one to believe that in the very near future the difficulties and even the incapacities of most elderlies to keep a moderate independence will increase exponentially [3]. When afflicted with frailty, a syndrome that tends to increase the range of cognitive, motor and psychophysical morbidities in elderly individuals, the probability of falls to them considerably increases, reaching the level of 59% higher when compared to non-frail individuals, even considering elderlies in the same age range [3].

The fall rate in old people above 65 years old in the North American population reached 28.2% in 1998 and increased to 36.3% in 2010 [4], and recent data reported a range of 3%–85% for prevalence but a much narrower range (21%–39%) for incidence rates of newly formed FOF after a fall event. Even with no fall during follow-up, 11.6%–23.3% of older persons reported new concerns about falls [5] suggesting a big trouble. These increasing percentages proportionally increased the amount of the resources intended to treat the consequences of these undesirable events [6] as it can be evidenced by the fact that in 2012 the associated medical costs for fatal fall accidents approached $616.5 million and $30.3 billion for non-fatal accidents, being that those values raised, in 2015, from $637.5 million for fatal falls and $31.3 billion for non-fatal cases. It was also verified that the incidence of falls and the total cost for falls associated treatments increased with age and had higher costs for women [7].

Data related to the alarming costs of treatment for falls and the growth of the elderly population in the world has raised debates about preventive solutions to ensure sufficient physical and functional conditions to minimize the range of incapacities that in parallel affects the human aging process. Upon this view, therapeutics programs including physical exercises applied alone and/or combined with other activities have been mentioned as indicated to minimize a variety of serious morbidities which affect millions of elderlies in the world [7,8].

Specifically related to falls, the evidences of exercise benefits are many, including fall prevention and rehabilitation of those [8–10]. However, not all interventions by use of exercises are capable of producing changes, such as for example, when mediated by low-intensity exercises to which the frail elderly person does not respond well. By the other side, as precaution against possible accidents, they normally do not do well with this exercises type or avoid engagement in these.

In case of difficulties for implementing exercises program which do not reaches an appropriate benefits to specific individuals as frail older adults, the use of the NIBS may be an appropriate resource to make the brain more efficient for the performance of certain neural functions impaired by the ageing and thus creating a proper dimension to respond well to the demands of certain exercises and benefiting from its execution. Research has shown the effects of NIBS on cognitive and motor functional gains in children, adults, and elderly people, being such gains usually associated to adequate modulation of specific brain waves [11,12].

The reference commonly sought out in NIBS modulatory effects for motor control events is that of an EEG characteristic of the Alpha rhythm (7-11 Hz) for events of a cognitive nature, whereas for the motor domain, the Alpha rhythm integrates with the sensory-motor rhythm (SMR) on a spontaneous EEG associated with general motor activity events and spinal motoneuronal activities during tonic motor contraction tasks [13,14].

Our considerations about the already know (1) benefic effects of the Alpha and SMR waves modulation upon human cortical functions (2) the range of benefits that physical and mental exercises can promote on the brain and (3) also upon the corporal functionality of people who practice exercises regularly were the literature evidence that provided us the theoretical basis to hypothesis here that the group of elderly adults that will receives the NIBS techniques conjunctly with the PMET will show higher decreases in the index of falls probability than the group that will receive only the PMET. Also, that the higher predicted improvement to this same group will be proportionally associated to the levels of the Alpha and SMR modulations this group will achieve.

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II. METHODS

Research Ethics

The study was approved by the Ethics Committee of the Federal University of Rondônia, according to CAAE number 2.631.588, and all volunteers or their respective legal guardian read and signed the Free and Informed Consent Form. By signing the consent form the volunteer agreed to voluntarily participate in this investigation. All doubts about the study, the tasks involved and the subjects' rights were clarified prior to the consent form being signed.

Study design

This study is experimental since it was composed by an experimental and control group and included a random selection of these groups to verify the effects of a physical and mental exercise program conjugated to the technique of non-invasive brain stimulation aiming at reducing the risk of falls in frail elderly people.

Volunteers

The volunteers were recruited from a population of elderly people living in two cohabitation centers for this type of individual, one of them being linked to the Health Department (CCI) and the other an independent Foundation (SESC), both located in Porto Velho-RO, Brazil. Initially, 308 elderly people of both sexes were recruited and submitted to the following inclusion criteria: (i) Minimum age of 65 years old and maximum of 80 years old; (II) desire to voluntarily participate in the entire study.

In order to define the groups of interest for the study, these 308 volunteers answered a questionnaire which was applied to identify who among them had suffer at least one fall in the 6 months prior to that moment of the selection procedure. This part of the total scrutinous defined the exclusion of 110 older adults. The 198 reminiscent volunteers were then examined by the use of the Mini Mental State Examination (MMSE) and the Edmonton Fragility Scale (EFS). The MMSE had it cut off for the volunteers' exclusion defined as being 20 points and the EFS cut-off score set at 7 to 10 points.

After the two above described sequential evaluations, only 59 elderly people remained being that 28 were classified as suffering from moderate fragility and 34 with light fragility. With the desistence of 02 of these initially classified individuals, the remaining 57 were randomly divided into a Fragile Experimental Group (FEG) and a Fragile Control Group (FCG), with 28 and 29 elderly adult individuals, respectively.

Figure 1 shows schematically the methodology for selection, classification and separation of the control and experimental groups for the present study.

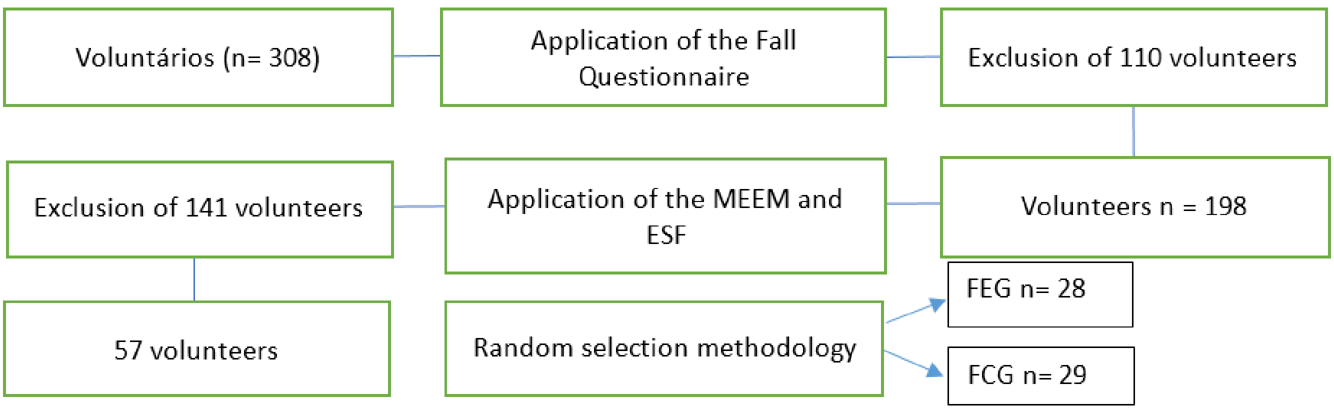

Fig.1: Sample Selection Methodology. Three hundred and eight elderly volunteers attended the call for the study, and after applying all the inclusion, exclusion and testing criteria for the sample selection, 57 volunteers were randomly divided into 2 groups, being a nominated as Fragile Experimental Group (n=28) and the other as Fragile Control Group (n=29).

The scores of the diagnostic evaluations that guided the formation of the experimental (FEG) and control groups (FCG) and the respective comparisons to verify homogeneity between them are presented in Table 1.

Table.1: Descriptive measurements of age, the MEEM and of the EFS identifying the statistics for comparison of distribution homogeneity for these variables between the groups, in association with inclusion/exclusion criteria. The p-values are related to the Mann-Whitney Test, with a significance index referring to p <or = 0.05.

Variables	FCG (n=29)	FEG (n=28)	*P* Values
Age	74.36±5.47	74±5.3	0.457
MEEM	23.5±2.82	23.0±2.71	0.508
EFE	8±1.24	8±1.16	0.913

As for the demographic profile of the groups, the age group of> 76 years of age was predominant followed by lower percentages for the age groups of 65 to 70 years old and 71 to 75 years old, respectively, with defined distribution equivalence between them. With regard to marital status, the majority are married individuals. The number of widows and widowers as well as unmarried and others is small in both groups. Other variables that constituted the demographic profile of the sample were sex, social income, marital status, education level and the number of falls occurring in the six months prior to this study.

Table.2: Data from the socio-demographic questionnaire. Responses from 57 elderly people who constituted the research groups and who answered the applied socio-demographic questionnaire. Items such as age, sex, marital status, education level, social income and number of falls were evaluated.

		Grupos		
		FEG (n= 28)	FCG (n= 29)	%
	65 a 70	07	08	25.00 - 27.50
Year	71 a 75	09	09	32.10 - 31.22
	76 >	12	12	42.88 - 42.88
	Married	23	22	82.14 - 75.86
Marital Status	Widowed	03	02	10.72 - 06.90
	Single and others	02	05	07.14 - 17.24
Sex	Women	14	14	50.00 - 48.27
	Men	14	15	50.00 - 51.73
Schooling	Complete Middle	17	19	60.71 - 65.51
	Higher	11	10	39.29 - 13.80
		01	01	
Social income	Up to 1 salary	10	11	3.58 - 3.45
	From 1 to 2 salaries	12	11	35.72 - 37.93
	From 2 to 4 salaries	05	06	42.85 - 37.93
	+ 4 wages	26	25	17.85 - 20.69
Nº of falls	1 a 2	02	04	92.86 - 86.20
	3 ou >			07.14 - 13.80

Procedures and Instruments

Data collection was performed in a 9x8m, well-ventilated room that was illuminated and prepared in order to avoid noise that could disturb the attention of the volunteers, thus providing conditions adequate to maintain focus and attention on tasks. All tests, as well as electroencephalographic recordings, were applied in an individualized manner, except for the non-invasive brain stimulation procedure (NIBS), since the instrument used for this allows for application of the stimulation to ten subjects simultaneously. The tests, MEEM and EFS, were used in the diagnostic phase in order to define the experimental and control groups and, therefore, were not used as data for comparison between pre and post-intervention, unlike the other tests and the EEG data.

Demographic profile and the used tests

The demographic profile of the volunteers was recorded at the time of groups composition, including the following factors: sex, age, marital status, drug use, social income, education level, physical activity level in the 12 months prior to admission to the study, frailty level and mental functional competence. After defining the groups, they were then tested in terms of falls propensity by the Tinetti Test (Tinetti) and the Motor Reaction Time Test under dual- choice task conditions (MRT). EEGs were also recorded in order to verify the functionality of Alpha and SMR bands in phases pre and post-intervention and the relationship of those waves with the other variables under investigation.

Edmonton Frail Scale (EFS)

This scale evaluates 9 domains, including two performance-based assessments: The Clock Drawing Test for cognition and the "Timed Up and Go" test for balance and mobility. The others are mood, functional independence, drug use, social support, nutrition, attitudes towards health, continence, medical illnesses, and quality

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of life. The maximum possible score is 17 points, which points to a high level of frailty. A score of 0-4 indicates lack of frailty, 5-6 apparent vulnerability, 7-8 slight frailty, 9-10 moderate frailty and 11 severe frailty [15].

Mini Mental State Examination (MMSE)

The MMSE was used to determine the mental health of the volunteers. Its application is based on specific questions grouped into seven categories, each with the purpose of evaluating the operational cognitive functions of the mind. Scores range from 0 to 30 points, with higher scores considered as better. The cut-off point was a minimum of 20 points, representing a medium/high educational level. This test was validated in Brazil by Bertolucci, Brucki, Campacci, & Juliano [16].

Tinetti Test

This test consists of 16 items: 9 for balance and 7 for gait. The test ranks characteristics such as gait speed, stride, symmetry and balance while the individual in test is standing in place and while spinning with one's eyes closed. The score for each exercise ranges from 0 to 1 or 0 to 2, with a lower score indicating poorer physical capacity. The overall score is the sum of the body balance score and the gait score. The maximum score is 12 for gait, 16 for body balance and 28 for the overall score. A score <19 points refers to a high risk of falling, between 19 and 24 points, a moderate risk of falling and above 24 points, a low risk of falling.

Acquisition of electroencephalographic signals

In order to verify the amplitude of the Alpha and SMR bands, EEG-Neurofeedback Procomp+ (Touch technology-Canada) was used. This equipment has its own grounding, condition that minimizes the interference of electrical signals or electromagnetic noise os quais if not controlled would impair the reliability of signal capture. For the present study, the distribution occurred at scalp point CZ and at auricular points A1 and A2, as recommended in the international 10-20 system [17] when the objective is the verification of the standard modulator of cortical areas associated with motor functions management and the mental executive functions [12].

Non-invasive Brain Stimulation

This procedure was performed using an Orion (Mind Place Technology-Canada) a photic and auditee synthesizer with binaural emission frequency pulses from which was selected the frequency of 8-12 hertz (Hz). This emission promotes a cerebral inter-hemispheric equalization causing an inter-hemispheric equalization that possibly establishes a neural field more conducive to learning and capable to facilitate any type of mental analyses due to the neural modulation this type of emission frequency causes[11,18]. This procedure was applied prior to physical/mental activities for a period of 20 minutes applied at all sections during the intervention period.

Training Program Procedures

All volunteers followed the physical and mental activity program at the Elderly Cohabitation Center (ECC) in which they were enrolled. The physical exercises that comprised part of the activities practiced at this Center were of light intensity, like low-intensity dance and stretches that avoided causing discomfort.

The intervention lasted 10 weeks including a total of 30 60-minute sessions, three times a week, with physical exercises of moderate or high intensity and mental exercises with a maximum number of 15 repetitions and 60-second intervals. Mental exercises were composed of logic games, information interpretation and decision making in which volunteers would need to think through and choose a response based on a proposed question. Twenty minutes of non-invasive brain stimulation were added prior to the exercise session only for the FEG.

The general intervention program was composed of NIBS combined or not with moderate or high intensity physical exercises, static and dynamic balance exercises and mental exercises. The NIBS when in conjugation with the PMED was only applied to the FEG in addition to the exercises the both groups already practiced on different days, format and time period in the ECC.

The series of physical exercises was composed of a warm-up, main session and relaxation. The 5-minute heating included conjugated moderately intense stretching exercises that were always performed on chairs; the subjects should be stretched until they feel a moderate discomfort in their joints and they are asked, in this type of exercise, to maintain the position for ten seconds.

The main part of the physical program was composed of squatting exercises, push-ups against the wall, unilateral squats with the aid of a walking stick, standing bent-over rows with walking stick, standing plantar flexion, shoulder elevation with walking stick, sitting plantar flexion, trunk flexion and extension, always in the same sequence.

Static balance exercises were practiced, such as walking in a line on one (alternating feet) or two feet. Dynamic balance exercises were the controlled gait which consisted of heel-to-toe walking and alternatively raising the knee to a 90º angle of knee in relation to the hip flexion.

During the practice of the mental exercises the examiner produced an auditory and/or visual stimulus demanding a rapid change from standing to squatting, from feet planted and changing to tiptoe, and in combination to changes of direction that varied from 60 to

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180 degrees. The practices were organized so that the mental practices associated to the exercises had 20 minutes of the 40 defined for this phase of the training.

The cool-down portion was practiced sitting in chairs in the form of breathing and by exercises similar to those proposed by oriental techniques such as Tai Chi Tchuen and Yoga.

Exercise intensity during each session was the greatest possible, though determined by the self-capacity and self-perception of effort of each of the elderly adults in the research, giving them the condition to stop the circuit and rest as much as they felt it necessary.

Statistical Procedures

Normality in the distribution of group scores was examined using the Shapiro-Wilks test. The results related to the Tinetti Test and Motor Reaction Time were analysed by means of the ANOVA ONE WAY test with Tukey's posterior test. The Alpha and SMR band results of the EEG were analysed by the Kruskal-Wallis test with a Dunn's posterior test. In order to verify the possible correlation between the MRT and FPI variables, Spearman's Correlation was used. All statistical analyses were performed using the program Prism Stat 5.0 with a significance level of 95%.

III. RESULTS

The NIBS conjugated to PMET decreased the propensity for falls and enhance motor reaction time

In relation to the effect of the proposed training on the propensity for falls, the FCG obtained an average score of 17.79±1.134 before the intervention period and 18.32±0.98 after the intervention period with no statistical difference between pre and post-intervention being $p > 0.05$ (Fig. 2A). However, the FEG obtained a mean score of 17.82±1.18 before the intervention period and 23.18±1.74 afterwards, showing a significative difference from post- to pre-intervention with $p<0.0001$ (Fig. 2A). There was an evident difference shown by $p<0.0001$ (Fig. 2A) between the post-intervention periods for both the intragroup and the intergroup comparisons favoring the FEG one.

Regarding the reaction time variable, FCG obtained a mean of 0.65 ± 0.07ms before the intervention period and 0.642±0.09ms after the intervention period, with no difference between the post-test and the pre-test with $p > 0.05$ (Fig. 2B). However, the FEG obtained 0.644 ± 0.07ms before the intervention period and 0.543 ± 0.043ms afterwards revealing a high difference between the post-test and the pre intervention MRT test being $p<0.0001$ (Fig. 2B). Also, to this MRT variable there was a clear difference as shown by $p<0.0001$ (Fig. 2B) between the pre and post-intervention periods for both the intragroup and the intergroup comparisons.

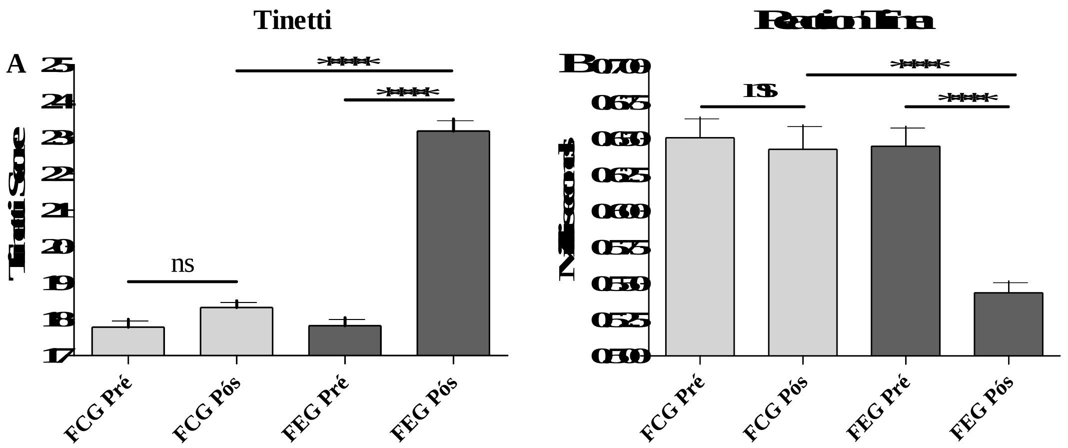

*Fig.2: A-B: Results of the Tinetti and the Motor Reaction Time tests.Elderly individuals separated into a Frail Control Group (FCG, n=29) and Frail Experimental Group (FEG, n=28) were submitted to 10 weeks of a combined physical and mental training program (CIP) and, before and after the intervention the propensity for falls and the motor reaction time was quantified and compared. ANOVA ONE WAY with Tukey's posterior test with a significance of 5% was used for intra and intergroup comparison. (ns = p> 0.05; ****=p<0.0001) respectively.*

The NIBS conjugated to PMET modulate the Alpha and SMR cortical wave pattern

In regards to the Alpha Band registered by the EEGs the FCG obtained an average of 8.64+7.72mV in the pre-intervention period and 7.41+5.71mV in the post-intervention moment with no difference between the post-test and the pre-test being $p > 0.05$ (Fig. 3A). On the other side, the FEG, before the intervention period, obtained 8.24+6.01mV and afterwards, 18.32+6.52, showing a difference between the post- and the pre-test as indicated by $p<0.001$ (Fig. 3A). In the intergroup comparison, the

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difference between the pre- to post-intervention periods was significative with p<0.0001 (Fig. 3A).

Looking at the performance of the groups for the SMR band the EEG registered for the FCG shown a mean of 8.13+4.75mV in the pre-intervention and 8.04+5.15mV in the post-intervention period with no difference between the post- and pre-EEG registration. The obtained value for the FCG intragroup comparison was of p> 0.05 (Fig. 3B). On the contrary, the registered score prior to the intervention period for the FEG was of 8.61+418mV and afterwards, 19.47+5.25mV, showing a difference between the post- and the pre-EEG registration of high significance with p<0.0001 (Fig. 3B). In the between groups comparison, also a high difference between the pre and the post-intervention periods was found with p<0.0001 (Fig. 3B) favoring the older adults who composed the FEG.

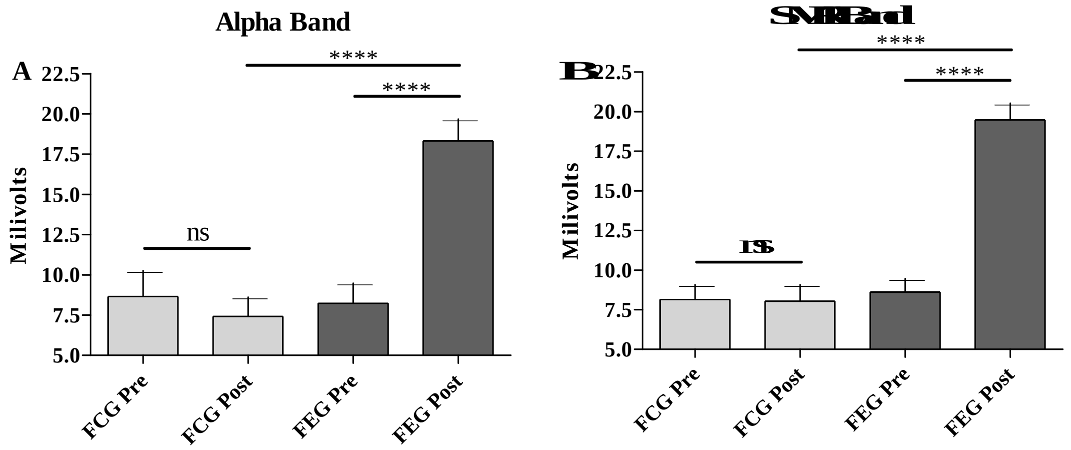

*Fig.3: A-B: Alpha and SMR band results from EEG. Elderly individuals separated into a Frail Control Group (FCG, n = 29) and Frail Experimental Group (FEG, n = 28) were submitted to 10 weeks of a combined physical and mental training program (CIP) and, before and after the intervention the amplitude of the Alpha and SMR bands were quantified by means of an EEG. The Kruskal-Wallis test with DUNN's posterior test with significance of 5% were used for intra and intergroup comparisons. (ns=p>0.05; ****=p<0.0001).*

Correlation between the modulation of Alpha and SMR cortical bands and Tinetti Test

There was a correlation between the amplitude patterns of Alpha as shown by *p* = 0.03 (Table 3) and the SMR Band indicated by *p*=0.006 (Table 3). No correlation was observed considering the same factors for the FCG, nor to any others of the factors here studied for both groups.

Table 3 describe the findings of the correlation run comparing all the factors to the Fall test (Tinetti Test)

*Table.3: Correlation Test. Elderly individuals separated into a Frail Control Group (FCG, n=29) and Frail Experimental Group (FEG, n=28) were submitted to 10 weeks of a combined physical and mental training program (PMED) and, after the intervention, the propensity for falls and motor reaction time along with electroencephalographic Alpha and SMR band amplitudes were quantified and correlations were determined by means of the Spearman Correlation test with a significance of 5%. (¢=Moderate Correlation; *=Statistical Significance).*

		Test TRM	Banda Alpha	Banda SMR
Tinetti Test	FCG	0.02	0.1	0.2
	FEG	0.09	0.34¢	0.45¢
***P* Value**	FCG	0.43	0.26	0.1
	FEG	0.31	0.03*	0.006*

IV. DISCUSSION

In the present study we investigated if non-invasive brain stimulation (NIBS) by binaural pulse emission coupled with physical and mental exercises (PMET) and/or the PMED without the use of the NIBS procedure could minimize the propensity of falls in elderly frail adults and how those possible effects would relate to the Motor Reaction Time (MRT) and with the Alpha and SMR cortical waves.

As shown in the Figure 1-A in which is plotted the scores medium of the group's performance in the test evaluating their indexes for falls tendency, we may verify

that the conjugated NIBS and PMET procedure significantly decreased the predicted rate of falls for the elderly adults in the FEG and that the PMED applied alone was not capable for significantly diminish the same investigated index for the elderly adults in the FCG.

In a more detailed explanation, the comparative analysis of the fall-related scores indicated that only the frail elderly subjects in the FEG changed from a high risk of falling to a moderate risk of underwent this type of accident, fact that indicates a good level of effectiveness of the conjugated program applied.

As we can understand from the results before presented, the conjunct application of NIBS and the PMED in addition to significantly reduce the propensity to falls for the elderly adults of the FEG may have, in consequence, reduced the likelihood of severe injuries that old individuals normally are committed in events of falls. In addition, due to the fact the test used for evaluating falls propensity includes the verification of most of the biophysical factors trained by the association of the NIBS to the PMED, we can affirm with some confidence here that the minimization in falls propensity the FEG demonstrated was due to gains promoted by the application of the conjugated training upon those referred factors.

In contrary to the conjugated training the PMET applied alone was not efficient enough to increase the performance of the FCG in the test that examined the levels of propensity to falls of this group. As we will see afterwards the same happened in relation to the MRT test in which this same group did not improve their performance in this variable after the PMED was applied in the intervention phase. As we can see in Figure 1-B, the gain of this group in terms of diminution of the probability of falls was very small and not statistically significant. The FEG, on the contrary did show a high and significant improvement in performance at the post intervention verification with his total members significantly minimizing their anteriorly verified levels of propensity to falls.

To explain the low effect of the PMED application for minimizing the probability of falls to the elderly adults in the FCG it can be post that this result is not in consonance with the literature in this line. Several studies have evidenced that exercises of higher or medium intensities increase the possibility of gains in physical and mental performance for all types of practitionerswith important effects upon their executive and cognitive functions of them [19–22]and particularly may decrease the probability of falls, even among elderlies who are the most fragile, with poor health, irregular body composition, impaired balance and/or fear of falling [23].

That is, although, the studies above mentioned provide enormous support to the findings related to the FEG that evidenced a high diminution of risk to falling by effects of the practice of the conjugated training program, the same results when related to the FCG do not applies in a same way. In fact, the PMED applied alone was not capable of effectively ameliorate the level of falls risk for this group in specific.

In face of the impressive differential effect of the PMED applied alone compared to its partial effects when applied with the NIBS procedure, we may advance an hypothesis here that 10 weeks of it application was not sufficient to cause more effective biophysical changes on the FCG, but when applied adjunctly with the NIBS procedure the ten weeks was enough to promote significant biophysical gains which the FEG may have used to perform so well in the test measuring probability of falls that the two groups performed.

Attending to the Figure 1-B now, we can verify that even in relation to the Motor Reaction Time (MRT) variable, the PMED when applied alone did not improve the performance of the FCG. However, its conjunction to the NIBS procedure may have, in some way, contributed to the significant post intervention performance of the FEG on this same variable. Comparing the pre and post intervention scores of the FCG we can see that this group diminished in about 0.08ms their mean response as the effect of the PMED application. Considering here the similarities of the two groups, we can reasonably consider that this particular effect of the PMED for the FCG may have been proportionally added to the NIBS particular effect upon the results of the FEG when submitted to the MRT test in the post intervention procedure.

In fact, it is evident that the FEG performance in the MRT test reduced in approximately 70 milliseconds from pre to post intervention measurements (Fig. 2B) demonstrating the positive partial effect of brain stimulation on this biophysical valence since the FCG reduction was of only 0,08 mseg by effect of the PMED. Considering the similarities of the groups, the question of why this happened can be answered as being in function of the conjugation of the NIBS to the PMED, and applied only to the FEG.

The results of the effects of the PMED intervention upon the FCG performance was not an expected one. There are a vast number of research that correlates physical exercises with good MRT capabilities [20–22].

Many are the authors who advocate the advantage of practicing physical exercises in order to effectively diminishes the probabilities for acquiring certain diseases as well for improving health, predisposition for work and life in an ample context [24].

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In addition a great part, physical exercises are perhaps the most important instrument to permit ageing people to maintain an adequate life style and capacity to execute the tasks inherent to the common life of any person [8,21].

Along with the same line of reasoning we have had until now, the observed decrease in the probability of falls experienced by the FEG may have had primarily implications with the NIBS application to this group, a procedure which have been commonly mentioned as capable of promoting direct improvement on the mental operational systems, being the Alpha and the SMR cortical waves centers of resulting common modulations.

According to the neurophysiologic notion which associates the human brain waves to their biophysical behavior we may reasonably admit that the modulations which occurred by effect of the conjugated intervention on the Alpha and SMR bands, shown in Figure 2-A, probably more than the exercises implicit in the program PMED, were the main causes for the results the FEG obtained in the test that examined the risk of falls of the elderly adults in each group. This supposition can gain support if we compare the results of the FCG whose components showed only a small and not significant diminution in falls risk after being submitted to the PMED.

Interestingly, if one recurs to the description of the correlation of the variables studied in this present research (Table3) will easily detect that the modulations of the Alpha and SMR cortical waves are derived of the increase of power emission of the both waves, even that in regard to the FCG the power emission increases were very small, with moderated correlations with falls propensity but to the FEG the correlations was high and significant. It also became clear that those increases were associated to a significant decrease in probability of falls to the FEG being that to the FCG the decrease in such probability was little.

The modulations in the amplitude of Alpha and SMR Bands as seen for the FEG in intra and intergroup comparisons (Figure 2 Ae B) were previously reported by Calomeni et al., (2017) who also evidenced, after the application of the NIBS program, significative increases in Alpha and SMR activity in the elderly adults with and without neurological disorders. In this regard, most of the increases in neural activity related with the bands Alpha and SMR seen in studies done with individuals in advanced age range are normally associated with improvements in the mental functions, conditions that usually interacts with better physical performance of them in many aspects of the human daily life [25].

We sawn in the in Figure 2 A-B, however, that a real improvement in power emission occurred only to the FEG in both waves and it was somehow a surprise since that at least to the SMR wave, we were expecting a different result. The SMR signals are recorded closer to the sensorimotor area and their amplitude is known to be reduced in relation to unsynchronized neural activities related to motor events, suggesting a possible electrophysiological signal of sensorimotor excitability [26]. In fact, they are located on the pericentral gyri and associated with the excitability of the cortico-spinal tract, as well as intracortical disinhibition of the primary motor cortex [27].

Such a neural organic organization compound to the SMR wave function expressed its interrelationship with movement and thought in an ample version. Many authors have provided evidence that the rhythms of the SMR wave are associated with activity in the somatosensory area and accessory to neuronal chains related to effectiveness and control of movement [28–30]. Thus, we hypothesized that a higher emission power of Alpha and, specially, of the SMR wave at expense of equalized inter-hemispheric fluctuations would positively influence the biophysical functions necessary to improve gait control and consequently the frailty of the elderly adults submitted to our experimentation.

It seems to be adequate to emphasize here that although we have not researched frailty in specific, the decrease in the probability of falls observed by the effects of the application of the NIBS and the PMED to the FEG may be an extension of these same effects upon frailty itself. There are an ample and consolidated notion that regular practice of physical exercise can promote a reduction of frailty in people in advanced age and that this reduction may also benefit the quality of life of them [11,31–33]. Even that the period of training was short, we creed that an intensive and well-planned program of exercise would be enough to shown us some interactive results. It was so in regard to the conjugated program but not to the one composed only by physical and mental exercises.

V. CONCLUSIONS

The conjugation of the NIBS to the PMED promoted a significant reduction in the probability of falls in the frail elderly, improved motor reaction time and modulated the Alpha and SMR cortical waves. Furthermore, it became evident the existence of correlation between the increase in the absolute power emission of these cortical bands and the decrease of the probability of falls for the investigated elderlies. These data together suggest a clear existence of a relationship between cortical waves modulation and the probability of falls in the frail elderly adults' individuals. Therefore, it is reasonable to say here that the such observed reduction in probability of falls is to be thought as being associated

with a reduction in the frailty condition of the elderlies, thus establishing a clear relationship of cause and effect between those two factors. Thus, considering this relationship we can considerate that the gains obtained by the FEG go beyond those related to the decrease in rate of falls and that also indicate that the cortical Alpha and MSR modulations also interact with the frailty factor. That is, a good mental functioning may provide a good biophysical basis against the possibility of becoming a frail individual.

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